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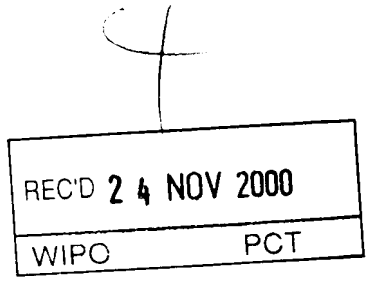

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

I also certify that by virtue of an assignment registered under the Patents Act 1977, the application is now proceeding in the name as substituted.

I also certify that the attached copy of the request for grant of a Patents (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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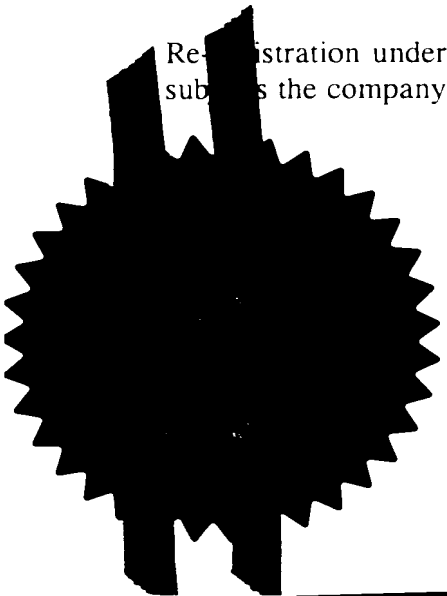

Signed

Dated 8 November 2000

GB9920071.9

By virtue of a direction given under Section 30 of the Patents Act 1977, the application is proceeding in the name of

CRANFIELD UNIVERSITY
Wharley End
CRANFIELD
Beds
MK43 0AL
United Kingdom

Incorporated in the United Kingdom

[ADP No. 06434740002]

Patents Form 1/77

Act 1977

The Patent Office

Request for grant of a patent

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The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference

137912

2. Patent application number
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9920071.9

24 AUG 1999

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

BTG INTERNATIONAL LIMITED
10 Fleet Place
Limeburner Lane
London EC4M 7SB

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

UK

SECTION 30 (1977 ACT) APPLICATION FILED

4. Title of the invention

CARBON COMPOSITE MANUFACTURING TECHNIQUES

5. Name of your agent *(if you have one)*

BINGHAM-Ian Mark

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Patents-Dept
BTG-INTERNATIONAL LIMITED
10-Fleet-Place
Limeburner-Lane
London--EC4M-7SB

Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or

b) there is an inventor who is not named as an applicant, or

NO

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Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature [signature] Date

IAN BINGHAM 24.8.99

12. Name and daytime telephone number of person to contact in the United Kingdom

IAN BINGHAM 0171 575 1568

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CARBON COMPOSITE MANUFACTURING TECHNIQUES

The present invention relates to an apparatus for and method of producing a composite structure and relates particularly, but not exclusively, to the production of vehicle structures and the like.

It is known to produce a composite structure by laying a plurality of fibres onto a first portion of a mould having a desired shape and introducing a resin material either during the laying up process or thereafter in order to ensure the fibres are bonded to each other and produce a component of the desired shape. It is also known to employ a mould having inner and outer portions which, upon assembly, are used to define the external shape of the component to be moulded. Additionally, it is also known to employ an injection technique in which resin is injected into the mould cavity during the manufacturing process. This injection step facilitates the impregnation of resin material between the fibrous structure and fills the mould cavity thereby to define accurately the final shape of the desired product.

Whilst the above processes provide a perfectly adequate method of manufacturing a composite component it does not lend itself readily to the production of complicated three-dimensional structures. Additionally, some structures can be somewhat bulkier than might be desired as producing strong and slim corners and / joints can be problematic.

It is an object of the present invention to provide a mould assembly for producing a composite structure which does lend itself to the production of complicated three-dimensional structures. Accordingly, the present invention provides a plurality of linked mould segments having an inner portion, which in a first assembled position act to define a mould and in a second disassembled position act to allow removal of the moulded article therefrom; a mould cover, which in co-operation with the assembled mould segments acts to define a desired mould shape; and pressurising

means, which in a first mode act to cause said mould segments to assume their assembled state and in a second mode allow the mould segments to assume their disassembled state.

20. A further object of the present invention is to provide a method of manufacturing a complex composite structure. Accordingly, the present invention also provides a method of manufacturing a composite structure including the steps of:

depositing a feed-stock comprising a core encased in a fibre covering into a first portion of a mould having a desired internal shape;

covering said deposited structure with a second portion of said mould;

exposing said structure to a source of resin; and

causing said resin to impregnate said fibres, thereby to form a structure.

The present invention will now be more particularly described by way of example only with reference to the accompanying drawings in which:

Figure 1 is an isometric projection of a vehicle substructure which might be produced in accordance with the method and apparatus of the present invention;

Figure 2 is a simplified representation of the segmented mould structure according to one aspect of the present invention;

Figures 3 and 4 illustrate one possible joint arrangement between segments of the mould structure and further illustrate the open and closed positions respectively;

Figure 5 is a diagrammatic representation of the mould structure of the present invention when fully inflated;

Figure 6 is a diagrammatic representation of the mould structure illustrating how the composite material may be applied thereto during the manufacturing process;

Figure 7 is a diagrammatic representation of the mould structure immediately prior to total encapsulation of the depository structure;

Figure 8 illustrates the encapsulation step and the introduction of the resin into the interior of the mould structure;

Figure 9 illustrates the mould structure in its disassembled state from which it will be possible to extract the moulded structure;

Figure 10 illustrates an intersection within the moulded structure;

Figures 11-18 illustrate various steps involved in the manufacture of a moulded structure in accordance with the present invention; and

Figure 19 illustrates in simplified form a machine suitable for supporting and rotating the basic mould structure onto which the composite material is deposited.

Referring now to the drawings in general, but particularly to Figure 1 it will be appreciated that a composite structure such as a vehicle space frame 10 is complex and not easily manufactured. The entire structure 12 comprises a number of portions which may include subassemblies such as subsection 14, and components, such as a door strengthening member illustrated generally at 16 and which is operably connected by means of a hinge 16a incorporated as a feature within the moulded structure. Additionally, features such as bumper mounting points 18 may be provided at other positions on the structure. Further components such as suspension members 20 may also be mounted to said structure by means of additional mounting points provided as features 22 incorporated into the mould structure during its production. More specific details of these arrangements are provided later herein.

A simplified form of the mould structure suitable for creating the composite structure of Figure 1 is shown in Figure 2. From Figure 2 it will be appreciated that the mould structure comprises a plurality of linked mould segments 24 each of which has an inner portion 26 onto which the composite material is laid during the assembly process described in detail later herein. In a first assembled position the mould segments act to define the mould whilst in a second, disassembled position, they act to allow removal of the moulded article there from. In order to facilitate movement between the assembled and disassembled positions the present invention proposes a pressurising means in the form of, for example, a reinforced silicone rubber bag 28 which may be inflated by introducing pressurised air or any other suitable fluid

through inlet 30, thereby causing said bag to inflate and move the mould segments 24 to their assembled position. Disassembly of the mould structure is achieved by withdrawing the air or other fluid from the bag either by simply releasing it therefrom or by positively withdrawing it.

Referring now more particularly to Figure 4 it will be appreciated that the segments 24 are jointed together by means of hinge means shown generally at 32. In the particular example of Figure 4 the hinge means comprises a flexible web member having a first portion 32a fixedly attached to first segment portion 24 and second portion 32b fixedly attached to an adjacent segment portion 24b. It will, however, be appreciated that other forms of hinge member may be employed in the performance of the present invention and this arrangement is shown by way of example only. In preparation, the flexible web portion 32 locates each segment 24 relative to its neighbour whilst providing sufficient flexibility for the segment to move between their two positions. In a simplified arrangement the hinge means may comprise a flexible material which forms the pressurising bag 28. However, it will be appreciated that a separate flexible material may be provided should that prove desirable. Also shown in Figures 3 and 4 are locating means in the form of, for example, tapered pins 34 and associated holes 36 provided on adjacent flange portions 38a, 38b of adjacent mould segments 24a, 24b. Operation of the pressurising means 28 will cause the hinged segments to be moved into interlocking relationship with each other in view of the fact that the pressurising force will be applied in the direction of arrows F of Figures 3 and 4. This force causes the segments to hinge relative to each other into their closed position and ensures the integrity of the hinged joint once assembled.

Referring now to Figure 5 which illustrates a simplified but assembled mould structure it will be appreciated that the segments 24, once assembled, act to define a mould structure onto which the composite material may be deposited. The degree of inflation of the bag is controlled by a reinforcing fabric and cables connecting the

nodal positions of the framework to each other and to the central mandrel (**this needs a further explanation and a suitable diagram**).

Deposition of the composite material is best illustrated by reference to Figures 11-18 attached hereto and to which reference is now made. The composite material comprises carbon fibre filament wound around a central core which, in a preferred arrangement, comprises a compressible core such as a foam material. It will, however, be appreciated that flexible or indeed rigid non compressible cores may be used to advantage. The creation of this feedstock is not the subject of this application and it is therefore not described further herein save for the fact that it comprises a woven carbon fibre outer casing 40 wound onto a core 42 prior to its deposition onto the mould structure. A suitable feedstock feeder/cutter apparatus shown schematically at 44 is employed to deposit the feedstock onto the mould structure such that a plurality of windings and/or discreet strips of feedstock are laid down as shown in Figures 11-18. Whilst the majority of the feedstock is wound in the form of a continuous tape it will be appreciated that this winding process may be stopped and then recommenced at any position of the mould structure such that localised areas may be provided with additional composite material in order to improve the strength of that portion. Preferably, the feedstock is wound onto the mould in a manner which causes it to form an interwoven structure at crossover positions within the mould structure. Such an arrangement facilitates the provision of additional strength at critical cross over points without introducing excessive additional material. In addition to the deposition of discreet lengths of feedstock it is possible to incorporate additional fabric, foam and metal inserts into the wound structure as the feedstock is supplied thereto. Such additions serve to enable the structure to withstand large or localised loads during use and/or mounting points for components which must be mounted to the basic moulded structure. As showed in Figures 11-18, the mould structure is filled with the feedstock whilst at the same time introducing any additional inserts (shown generally at 46) and the mould is then overfilled by a small

amount such that, upon closure of the mould the feedstock is compressed slightly prior to the injection step.

The encapsulation and injection steps are possibly best illustrated by reference to Figure 7 and 8 from which it will be appreciated that the second part of the mould is bought in to encapsulate the laid down material and is then secured in position by any suitable mechanical means such as the bolted arrangement of Figures 15-17. It will be appreciated that whilst Figures 7 and 8 illustrate a total encapsulation type arrangement one need only actually encapsulate the portions containing the laid down material and, consequently, the mould need not provide a total enclosure. In order to facilitate the rapid assembly of the tooling one might employ pneumatic or robotic actuation systems (not shown) which move the second portion or portions of the mould into position and retain them there during the subsequent steps. The act of introducing the second portion 46 causes the feedstock to be compressed and ensures the fibre structure and any additional inserts 46 are kept still during the subsequent infusion step. The second portion of the mould is preferably coated with a silicone layer to aid sealing during infusion and release once the component has been cured. The resin injection step is best illustrated by reference to Figure 8 and 17 from which it will be appreciated that by applying a vacuum to the interior of the mould one can draw the resin material into the interior of the mould and cause it to pass along the strands of the fibre, thereby passing between and coating the fibre with the resin which also acts to define the outer surface of the finished article in view of the fact that it contacts the surface of the mould structure itself. The use of a vacuum step is preferred over that of a positive resin injection step as the simple vacuum step makes the job of sealing significantly easier and reduces loads on the tooling associated with the mould process. Whilst not absolutely necessary, it will be appreciated that a small additionally internal pressure may be applied to the pressurising means to help ensure that the segments 24 seal against the second portion of the mould.

Once the resin is injected the mould is allowed to cure (is this at room temperature or heated?) and the second portion of the mould is removed and the pressurising means deflated for the extraction of the completed space frame. Any mould/debris is removed from the space frame and the tooling is then cleaned and prepared to re-use once again.

Referring now to Figure 10, it will be appreciated that intersections 50 are manufactured by introducing diverting elements in the form of raised sections 52 thereby to divert a portion of the feed-stock around the corner created by said section. In the effect, this introduces a triangular gap in the space frame at the nodes which may cause splitting along the beam sections and, hence, it is advisable to insert additional fabric reinforcements (as described above) around such areas.

Figure 19 illustrates in a very simplified form a machine suitable for supporting and rotating the basic mould structure onto which the composite material is deposited. The machine 60 comprises a support frame 62 having a feedstock supply head 64 mounted onto a two axis positioning head 66. The head 66 is mounted on and translatable along bridging member 68 which is, itself, translatable along frame 62. The basic mould structure formed of segments 24 is mounted for rotation about a longitudinal axis of the frame 62 such that, one translation of the feed-head 64 and rotation of the mould structure it is possible to deposit the feedstock into the mould in the manner described above. This figure also illustrates the cross over or inter meshing relationship that might be employed at junction points within the mould structure, thereby to increase the strength of the final article.

CLAIMS:

1. A mould assembly for producing a composite structure comprising:

a plurality of linked mould segments having an inner portion, which in a first assembled position act to define a mould and in a second disassembled position act to allow removal of the moulded article therefrom;

a mould cover, which in co-operation with the assembled mould segments acts to define a desired mould shape; and

pressurising means, which in a first mode act to cause said mould segments to assume their assembled state and in a second mode allow the mould segments to assume their disassembled state.

2. An assembly as claimed in Claim 1 in which said mould segments are linked by hinge means.

3. An assembly as claimed in Claim 2 in which said hinge means comprises flexible material extending between adjacent mould segments.

4. An assembly as claimed in Claim 3 in which the flexible material comprises a portion of the pressurising means.

5. An assembly as claimed in claim 4 and further including templates located at junctions of the mould assembly for receiving material to be moulded.

6. An assembly as claimed in any one of the previous claims and further including location means for locating adjacent mould segments relative to each other upon assembly of the mould.

7. An assembly as claimed in Claim 6 in which said location means comprises tapered pins and corresponding holes provided on mutually confronting portions of adjacent mould segments.

8. An assembly as claimed in Claim 6 or Claim 7 in which each mould segment includes a flange portion upon which said location means is provided.

9. An assembly as claimed in any one of Claim 1 to 8 in which the mould segments have a channel like cross-section, thereby on assembly of the mould to define an externally accessible mould.

10. An assembly as claimed in any one of Claim 1 to 9 in which said pressurising means comprises a pneumatic pressurising means.

11. An assembly as claimed in Claim 10 in which the pressurising means comprises one or more inflatable structures which, upon inflation, press the mould segments into their assembled position.

12. An assembly as claimed in claim 11 and further including sequencing means for sequencing the inflation of the one or more inflatable structures.

13. An assembly as claimed in any one of the preceding claims and further including a material feed for supplying composite material to said mould.

14. An assembly as claimed in any one of the preceding claims and further including binder application means for applying binder material at one or more positions on said structure.

15. An assembly as claimed in any one of the preceding claims and further including resin injecting means for injecting resin into the moulded structure once said structure is laid within the mould.

16. An assembly as claimed in Claim 15 in which the resin injecting means comprises a source of resin operably connected to a portion of the interior of the mould segments and vacuum means also connected to the interior of the mould for reducing the pressure therein, thereby to draw resin through the interior of the mould and into the structure of the article being moulded.

17. An assembly as claimed in any one of the preceding claims and including a mould cradle and rotation means for rotating the mould relative to the cradle.

18. An assembly as claimed in any one of Claims 14 to 17 and further including means for rotating the feed means around the mould.

19. An assembly as claimed in any one of the preceding claims including locating means for locating "features" during the moulding process.

20. An assembly substantially as described herein with reference to Figures 1 to 19 of the accompanying drawings.

21. A method of manufacturing a composite structure including the steps of:

depositing a feed-stock comprising a core encased in a fibre covering into a first portion of a mould having a desired internal shape;

covering said deposited structure with a second portion of said mould;

exposing said structure to a source of resin; and

causing said resin to impregnate said fibres, thereby to form a structure.

22. A method as claimed in Claim 21 in which the structure comprises a plurality of segments including the step of depositing a plurality of said segments within said first portion of the mould.

23. A method as claimed in Claim 22 in which said plurality of said deposited segments are of various cross-sectional sizes.

24. A method as claimed in Claim 21 or Claim 22 in which said structure or segments have cross-sectional sizes which vary along their length.

25. A method as claimed in Claim 21, 22 or 24 in which said structure or structures comprise individual structures or segments whose cross-sectional size and shape varies along their length.

26. A method of manufacturing as claimed in any of claims 20 to 25 claims in which the mould comprises a multi-limb mould having crossing portions and said structures or segments are deposited over said crossing portions in inter-meshing cross-over relationship.

27. A method of manufacture as claimed in any one of Claims 21 to 26 in which at least a portion of the deposited structure or segment is wound onto said mould.

28. A method as claimed in any one of Claims 21 to 27 in which resin is deposited during laying down of the structure or segment.

29. A method as claimed in any one of Claims 21 to 28 in which the resin is deposited by being drawn into said mould from a source thereof during the evacuation step.

30. A method as claimed in any one Claims 21 to 29 including the further step of incorporating or embedding "features" within said structure during lay-up thereof.

31. A method as claimed in any one of the preceding claims in which the core comprises a deformable core.

32. A method as claimed in Claim 31 in which the core comprises a closed cellular material.

33. A method as claimed in any one of claims 21 to 32 in which resin is introduced into the fibres by means of a vacuum process.

34. An article when produced in accordance with the method as claimed in any one of the preceding claims.

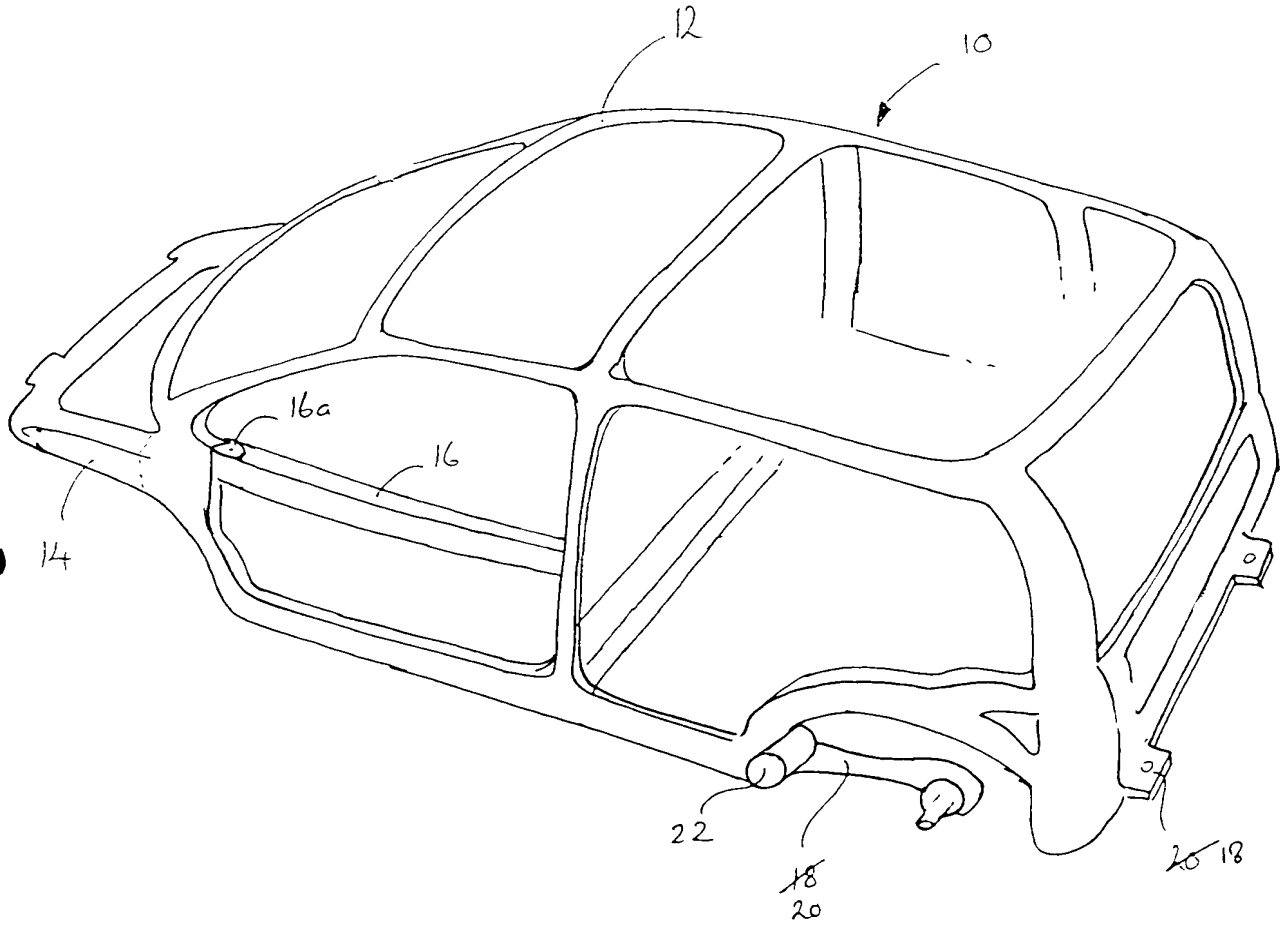

Fig 1

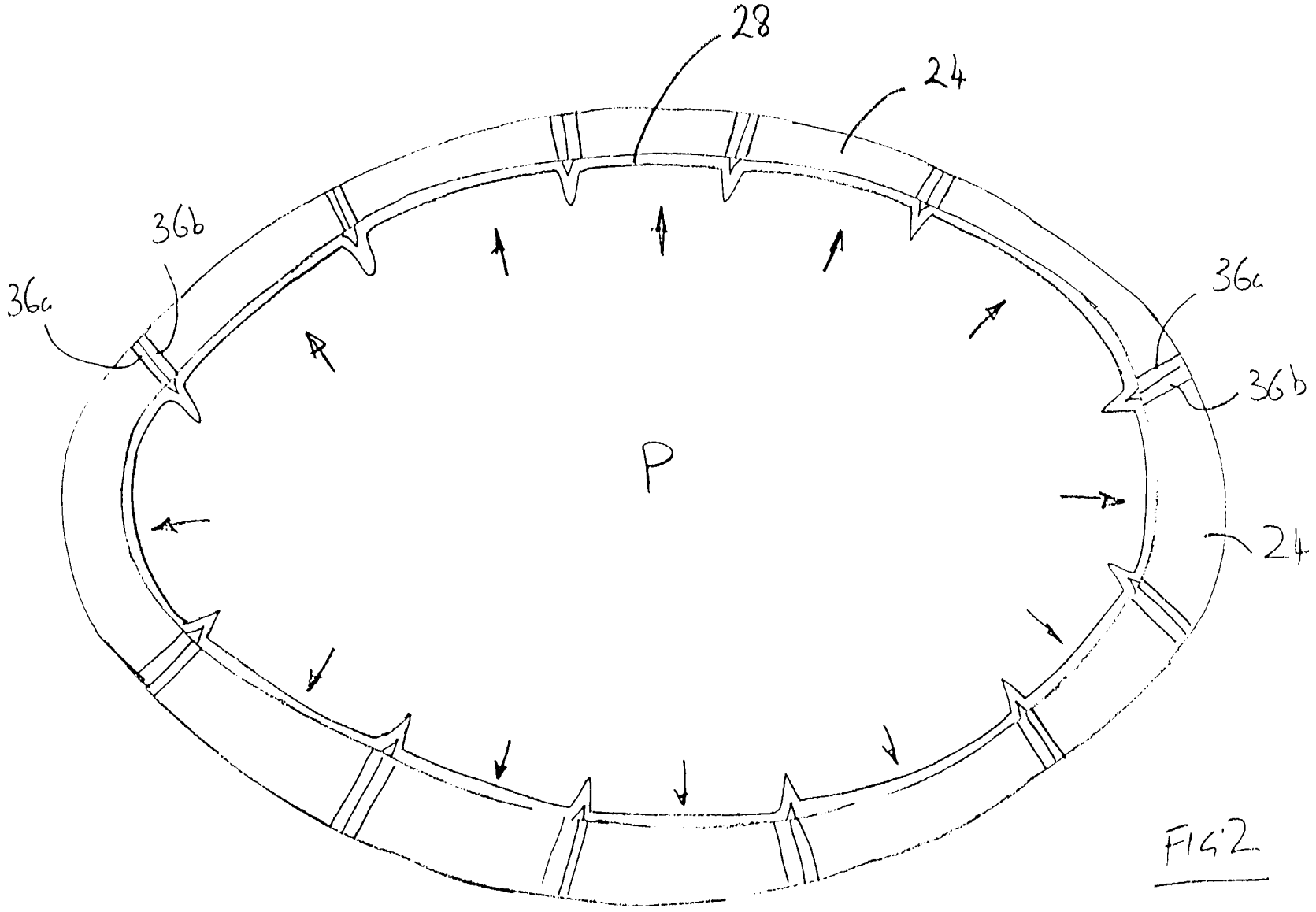

FIG 2

ASCC - Composite Spaceframe Manufacture
Stage 1

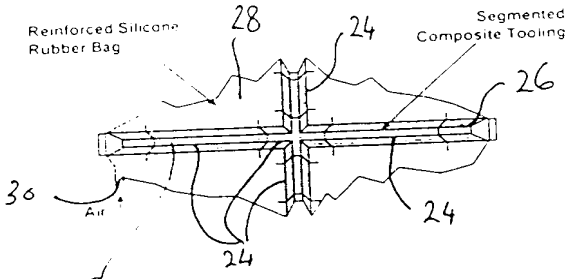

Fig 3

Channel section tooling is produced on a splash off the styling clay

The assembly is coated with flexible membrane of silicone/rubber, reinforced with a fabric (glass fibre, polyester) in order to produce a bag, similar to those used on inflatable marine craft

ASCC - Composite Spaceframe Manufacture
Stage 1(b)

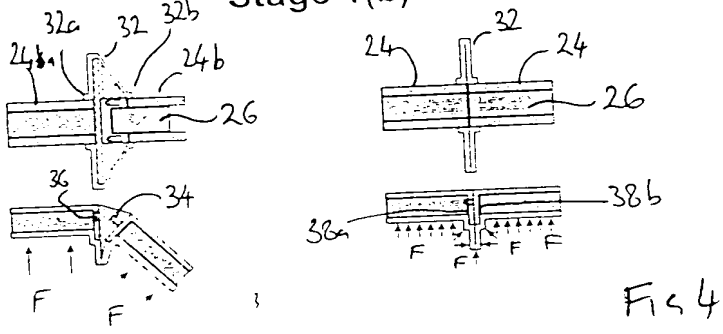

Fig 4

The composite channel sections are terminated by flanges, which are encapsulated in large flaps of the bag material, so the framework may be disassembled

Tapered pins are used to locate the channels, and to lock their position once the bag is fully inflated.

The internal bag pressure pushes the flanges together and seals the joint.

ASCC - Composite Spaceframe Manufacture
Stage 2

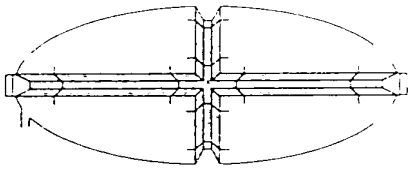

Fig 5

The bag is inflated so the channel sections fold out and lock together, into the correct position.

The degree of expansion and final shape of the inflated bag is limited and controlled by the reinforcing fabric and cables, connecting the nodal positions of the frameworkto each other and the central mandrel.

ASCC - Composite Spaceframe Manufacture
Stage 3

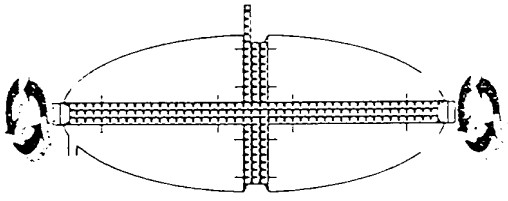

Fig 6

The fibre/foam feed stock is then wound over the form in order to fill the channel sections.

Additional fabric, foam and metalic inserts are introduced at this point, so the strucure is capable of withstanding the large or localised loads during service.

The channel is over-filled by a small percentage, so that the foam is held slightly in compression prior to injection.

ASCC - Composite Spaceframe Manufacture Stage 4

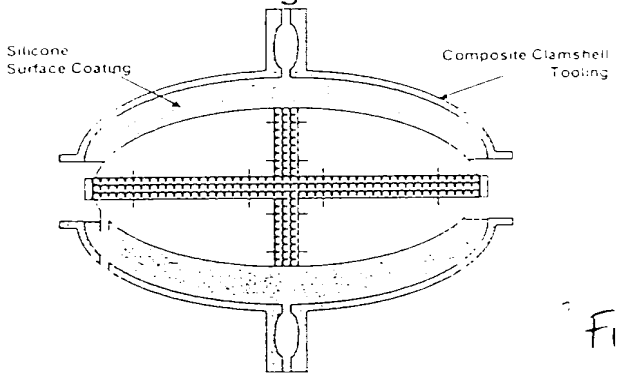

Fig 7

The clamshell, defining the external form of the spaceframe is bought into position around the assembly.

This action compresses the preform and ensures the fibre package and additional inserts are kept still during infusion.

The clamshell is coated with a silicone layer to aid sealing during infusion and release once the part is cured

ASCC - Composite Spaceframe Manufacture Stage 5

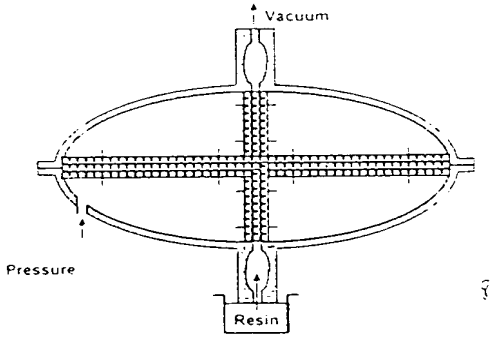

Fig 8

The channel is evacuated and resin introduced into the part, impregnation is by vacuum only as this makes the job of sealing significantly easier and reduces the loads on the tooling.

A small addidtional internal pressure is applied to the bag to help to seal the channels properly.

ASCC - Composite Spaceframe Manufacture
Stage 6

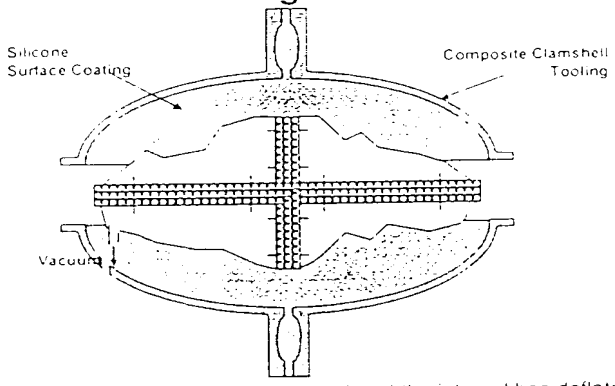

Fig 9

Once the part is cured, the clamshell is removed and the internal bag deflated for extraction from the completed spaceframe.

Flash is removed from the spaceframe and the tooling is cleaned and prepared for the next run.

ASCC - Composite Spaceframe Manufacture
Dealing with Intersections

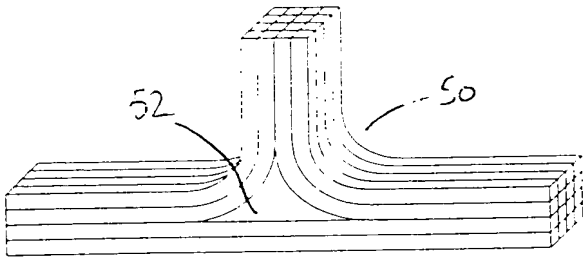

Fig 10

Intersections are dealt with, by introducing raised sections in the tooling to divert a proportion of the feed stock around the corner.

This introduces a triangular gap in the framework at the nodes which may encourage splitting along the beam sections, so additional fabric reinforcement is introduced around problem areas

12

13

1 Lay Band of Dry Tow Into Channel Section

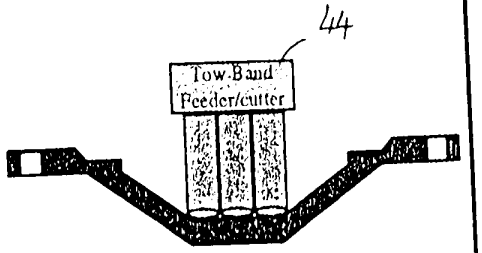

Fig 11

2 Build Up Layers

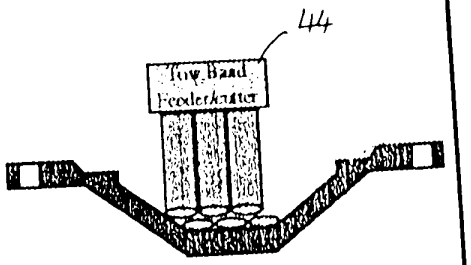

Fig 12

3 Include Core/ Load Bearing Inserts

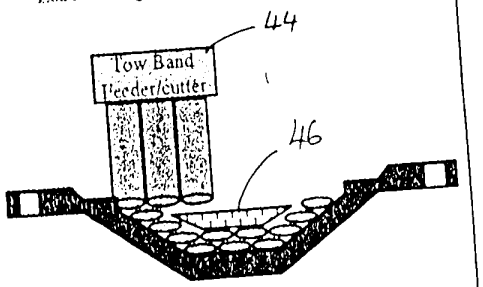

Fig 13

4 Completely Fill Channel Section

14

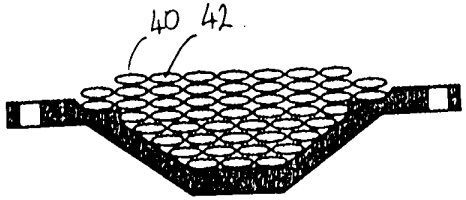

Fig 14

5 Introduce Top Surface

15

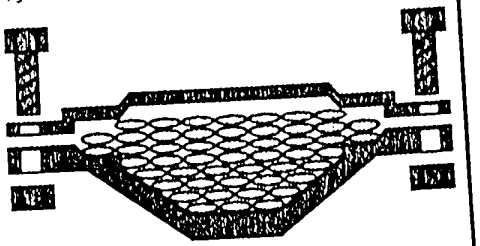

Fig 15

6 Bolt Down and Seal Tool

16

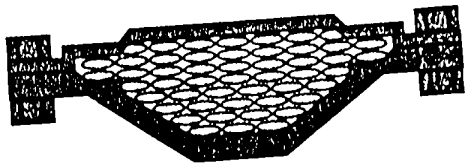

Fig 16

7 Inject Resin

17

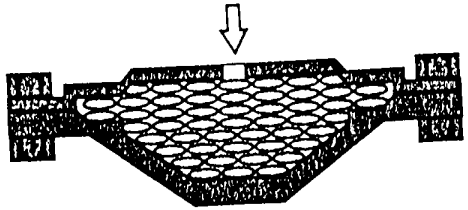

Fig 17

8 Cure part and Remove from Tool

18

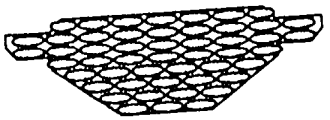

Fig 18

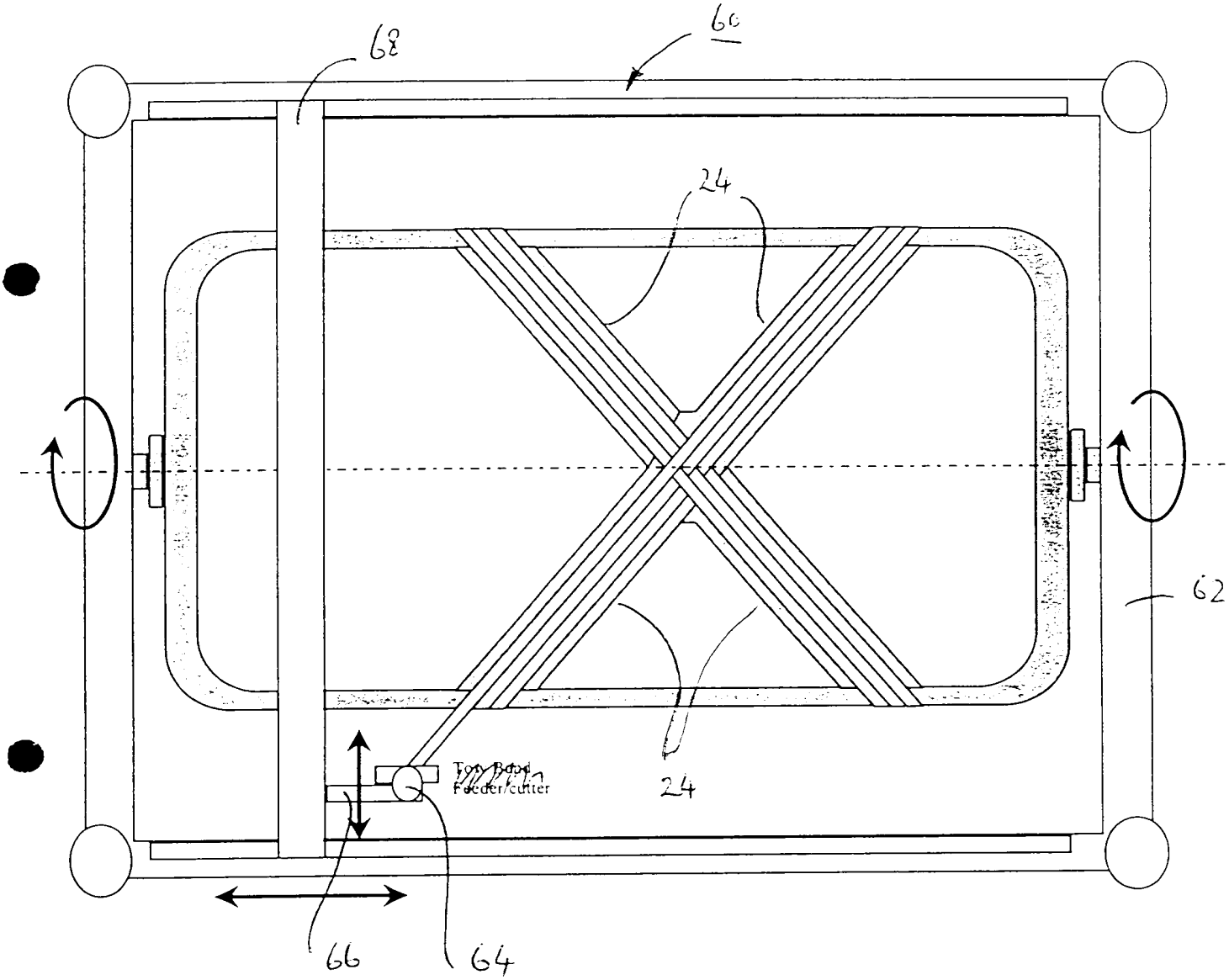

Fig 14